PRESOLAR GRAPHITE GRAINS FROM ORGUEIL: SOME UNRESOLVED ISSUES. M. Jadhav[1], S. Amari[1], E. Zinner[1] and T. Maruoka[1*], [1]Laboratory for Space Sciences and the Physics Department, Washington University in St. Louis, One Brookings Dr., St. Louis, MO 63130, USA. (manavijadhav@wustl.edu) [*]present address: Graduate School of Life and Environmental Sciences, University of Tsukuba, Ibaraki 305-8572, Japan.

Introduction: In previous years, multi-element (C, N, O, Al-Mg, Si, K, Ca, and Ti) isotopic evidence has indicated that graphite grains from Orgueil have multiple stellar sources [1,2]. Most low-density (LD) grains come from supernovae (SNe) while high-density (HD) grains originate in low-metallicity asymptotic giant branch (AGB) stars, SNe and born-again AGB stars. In this abstract, we highlight some of the problems we encountered while studying presolar graphite grains from Orgueil and trying to constrain the nucleosynthetic processes in their stellar sources.

Summary of isotopic studies: We found that presolar graphites from Orgueil tend to have C, N, O, Al-Mg and Si isotopic properties that depend on density. Many LD grains have ^{15}N, ^{18}O, ^{28}Si excesses and high inferred ^{26}Al/^{27}Al ratios, indicating an origin in SNe. Two LD grains with ^{28}Si excesses contain radiogenic ^{44}Ca from the decay of ^{44}Ti. Most HD graphites contain ^{29}Si and ^{30}Si excesses that correlate with ^{12}C excesses [1] – a signature expected from low-metallicity AGB stars. However, most HD grains have terrestrial N and solar O isotopic ratios and smaller ^{26}Al/^{27}Al ratios than LD grains. Four HD grains show evidence for the initial presence of ^{44}Ti, which confirms an origin in SNe. Some of the HD grains with low ^{12}C/^{13}C ratios (less than 20) have extreme anomalies in Ca and Ti isotopes that match those calculated for the He-shell of AGB stars [2]. Born-again AGB stars (like Sakurai's object), which suffer a very late thermal pulse, are expected to simultaneously exhibit low ^{12}C/^{13}C ratios and high abundances of s-process elements on their surfaces. We hypothesize that such stars could be the stellar sources of the highly ^{13}C-enriched graphites with large Ca and Ti anomalies [2].

Comparison of presolar graphites from Orgueil and Murchison: Orgueil graphite grains appear to be similar to Murchison graphite in their isotopic properties. Morphologically, the onion-type grains observed in Orgueil are similar to the HD Murchison graphites but, unlike in Murchison, are abundant in both the LD and HD fractions. Very few cauliflower grains have been observed in any density fraction of Orgueil. Another puzzling characteristic of Orgueil graphite is that the HD grains are, on average, much larger than the HD Murchison grains. Orgueil HD grains range up to 35 µm in diameter while the largest grain found in the Murchison HD fractions has a diameter of 19 µm, but most of the Murchison KFC1 grains are smaller than 3 µm (see Figure 2 in [3]).

The lack of N anomalies in HD grains is a common trend in the graphites from both meteorites [3]. In the KE3 fraction (1.65 – 1.72 g cm^{-3}) from Murchison about a third of the grains have a SN origin. The abundance of ^{18}O-rich grains decreases with increasing density and, in fact, such grains have not been observed in the highest Murchison density fraction KFC1 (2.15 – 2.20 g cm^{-3}). A similar trend is observed in the abundance of ^{18}O-enriched grains among the density fractions of Orgueil. Recent NanoSIMS analysis of HD graphite grains (KFB1) from Murchison (Amari et al. 2005) indicate that they also have ^{30}Si excesses, similar to the ones seen in the HD fractions from Orgueil (OR1f, 1g, and 1i); they are thus believed to have originated from low-metallicity AGB stars. There is no Ca and Ti isotopic evidence for Murchison graphite grains from born-again AGB stars, like the Orgueil grains discussed by [2]. However, a population of grains with ^{12}C/^{13}C around 10 exists in all the density fractions of Murchison as well. Additional isotopic measurements on these ^{13}C-enriched graphites from Murchison will be needed to better constrain their stellar sources.

Huss et al. [4] claim that a homogenous mixture of presolar grains was inherited by members of all the chondritic classes of meteorites and survived in the most primitive of these classes. After parent body formation, thermal and aqueous alteration processes could have affected the presolar grain populations to varying extents. Thus, the presolar grain populations from Orgueil and Murchison and their abundances are expected to differ from one another because, even though both meteorites show very little evidence of thermal metamorphism, the matrix mineralogy of Orgueil indicates extensive aqueous alteration (e.g. [5]). It is also possible that the initial presolar grain population was sorted in the early solar system according to physical properties or selectively destroyed by partial evaporation of solids. The destruction of certain presolar phases or of a certain type (e.g., cauliflower graphites in Orgueil) within a certain phase, in the laboratory during chemical separation techniques also cannot be ruled out.

Other unresolved issues: There remains a large number of problems related to the study of presolar graphite grains that still need our attention:

a) There is an old He/C – He/N SN zone mixing problem in that models predict a negative correlation between the $^{12}C/^{13}C$ and $^{15}N/^{14}N$ ratios on the one and $^{26}Al/^{27}Al$ ratios on the other hand. In contrast, a large number of SN graphite grains exhibit high $^{12}C/^{13}C$, $^{15}N/^{14}N$, and $^{26}Al/^{27}Al$ ratios, simultaneously. A similar problem is encountered while attempting to explain the SiC-X grain data [6]. We hope that the grain data serve as an impetus to SN nucleosynthesis modelers to re-examine and/or refine their calculations.

b) There are many observations that point to equilibration of isotopic systems in graphite grains. For example, equilibration is the only reasonable explanation that HD grains from Murchison have essentially normal N isotopic ratios although they have a large range of C isotopic ratios [Hoppe et al., 1995]. Many more examples are found among the Orgueil graphite grains:

Some grains that contain SN signatures contain $^{18}O/^{16}O$ and $^{26}Al/^{27}Al$ ratios that are much smaller than those calculated for SN nucleosynthetic models, while other isotopic ratios seem to fit SN models reasonably well. The relatively small anomalies obtained in the grains indicate that the O and Mg isotopes may be largely equilibrated in these SN grains. This equilibration could have occurred in the laboratory or on the parent body. The exact mechanism for such a dilution process needs to be investigated.

In the HD fraction of Orgueil (OR1f) we found grains with extremely large Ca and Ti anomalies but almost normal N, O, Mg, and Si isotopic ratios. Neutron-capture reactions that affect the Ca and Ti isotopes should have also affected the Mg and Si isotopes considerably. The nature of the equilibrating processes that affect only Mg and Si isotopes, and not Ca and Ti isotopes needs to be identified and better understood. Also, for some reason this isotopic dilution affects HD graphites much more than LD grains [1,2].

Sources of possible contamination also need to be identified as contamination makes constraining the stellar sources of the grains complicated [e.g., 7].

c) There seems to be a clear distinction between the sources for LD and HD graphites from Murchison. Apart from a few exceptions, LD grains are from SNe while HD grains originate in low-metallicity AGB stars. This distinction breaks down as we analyze more and more presolar graphite grains from Orgueil. Multiple stellar sources for grains of different densities might be an inherent property of presolar graphite grains in Orgueil or an artifact. Every density fraction of Orgueil contains a large amount of macromolecular carbon and most graphite grains are found embedded in this material. It is entirely possible that grains having different densities remain embedded in this carbonaceous material and were not separated completely during the density separation and grains with different densities could be mixed in with the others (Remusat L., pers. comm.).

The presence of this macromolecular carbon in all density fractions of Orgueil graphites also makes it virtually impossible to determine their abundance, because grains embedded and hidden in this IOM will not be counted. It is essential to study the structure and composition of this macromolecular carbon to further refine the chemical separation procedure used to extract presolar graphite grains from meteorites, especially those similar to Orgueil that are very rich in organics.

d) Isotopic studies of subgrains found within graphites similar to the one carried out by Stadermann et al. [8] are very important to establish the exact nature and source of the isotopic anomalies seen in these grains. For example, most Ti measured in the graphites is found in subgrains, while Ca is uniformly distributed in the parent grain. The host grain and its subgrains could have formed under completely different condensation conditions, and the Ca and Ti anomalies we find in a single grain could originate from distinct layers of the stellar source. Such a scenario is not considered when the stellar sources of the grains are discussed based on the isotopic ratios measured in the whole grain.

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